LSME- 5 0 6 glv RF

| LAWRENCE BERKELEY LABORATORY-UNIVERSITY OF CALIFORNIA ENGINEERING NOTE | | CODE:: AL05-34 | SERIAL: M 7274 | LSME: | PAGE 1 OF 6 | Advanced Light Source |
|---|---|---|---|---|---|---|
| AUTHOR: Tom Henderson | DEPARTMENT: Mechanical Engineering Dept. | LOCATION: Berkeley | | DATE: May 12, 1992 | | |

# ALS - STORAGE RING

# VACUUM ASSEMBLY / INSTALLATION

# STRAIGHT SECTION RF FLEX BANDS

**This note has been reviewed by:**

Kurt Kennedy Kurt Kennedy

Alan Paterson J. A. Paterson 5/13/92

Roderich Keller Roderich Keller

Glen Lambertson Glen R Lambertson

## Introduction:

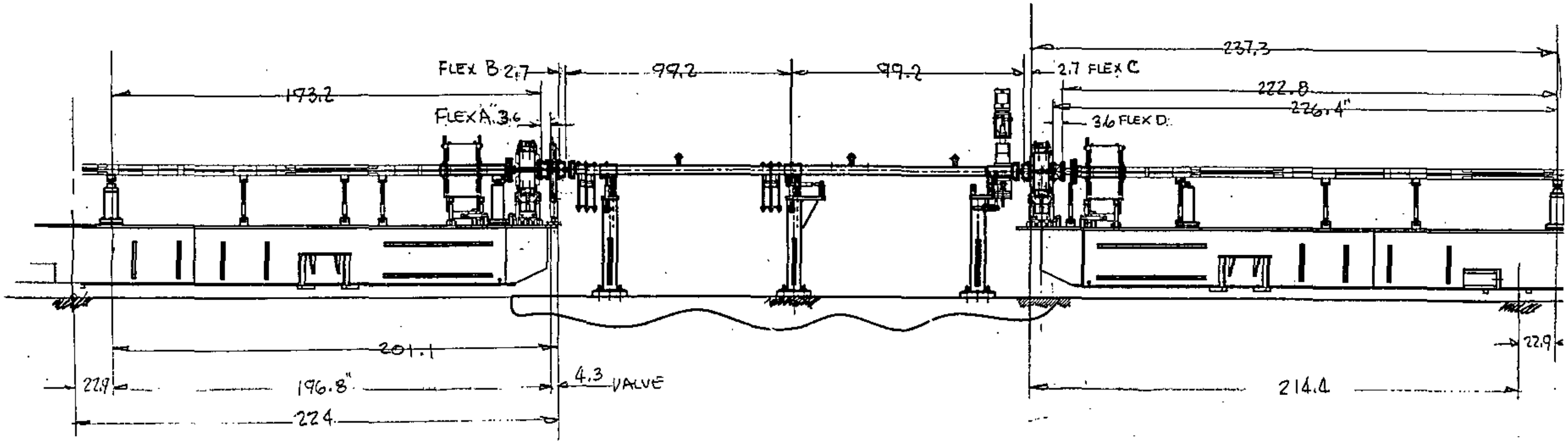
Recently it was realized that the design for the RF flex bands inside the vacuum bellows in the storage ring straights need to be re designed to avoid any bowing of the bands as this could cause RF heating. Bowing of as little as 1mm could cause sufficient RF heating to expand the flex bands causing additional bowing and heating. This requirement along with the fact that we expect to install these assemblies at 21° C and to eventually operate at nominally 24° C, required us to re design the flex band assembly.

This note describes the design that we expect to implement and records the expected thermal movements. A prototype will be fabricated and RF tested as soon as possible.

## Criteria used for design:

Assume that installation will be done at 21° C.
Thermal stabilization nominal temp. is 24° C ± 1° C
Because high temperatures can cause the flex bands to bow causing heating and probable damage, we design for extra safety factor on the high end. Use 29° C as a temp. at which the bands will start to bow.
On the lower end of the temperature tolerance use 17° C as the limit for operation.
Normal operating temp. of these assemblies is designed to be 27° C to 18° C with a 2° C safety margin on the high end and a 1° C safety margin on the low end.

## Contents of this note:




DIMENSIONS USED FOR THERMAL
MOVEMENT CALCS. AT FLEX A, B, C, & D.

PG 2

# ESTIMATED RF FLEX JOINT DEFLECTIONS

5/11/92
Tom Henderson

Assume the following:
Initial installation of flex joint is at 21 deg C (69.8F)
Case 1 = Everything heats to 27 deg C (80.6F) — 21 to 27 = +6 deg C
Case 2 = Everything cools to 18 deg C (64.4F) — 21 to 18 = -3 deg C
Case 3 = Bake aluminum to 140 Deg C (284F) (Girder at 21 C...69.8F)

Steel = 12 x 10-6 in/in/C — 0.000012
Alum = 22 x 10-6 in/in/C — 0.000022

**Case 1 — all change +6 deg. C**

| FLEX A (nominal length = 3.6) | | |
|---|---|---|
| Girder elong (L=196.8) | sect cbr elong (L=193.2) | flex A shorten |
| 0.014 | 0.026 | **0.011** |

| FLEX B (nominal length = 2.7) | | |
|---|---|---|
| Girder elong (L=224) | Spool elong (L= 99.2) | flex B shorten |
| 0.016 | 0.013 | **0.029** |
| 0.019 | 0.015 | **0.034** |

(+7 deg C)

| FLEX C (nominal length = 2.7) | | |
|---|---|---|
| Girder elong (L=214.4) | Spool elong (L= 99.2) | flex C shorten |
| 0.015 | 0.013 | **0.029** |

| FLEX D (nominal length = 3.6) | | |
|---|---|---|
| Girder elong (L=226.4) | sect cbr elong (L=222.8) | flex C shorten |
| 0.016 | 0.029 | **0.013** |

**Case 2 — all change -3 deg. C**

| FLEX A | | |
|---|---|---|
| Girder shorten (L=196.8) | sect cbr short (L=193.2) | flex A longer |
| 0.007 | 0.013 | **0.006** |

| FLEX B | | |
|---|---|---|
| Girder shorten (L=224) | Spool short (L= 99.2) | flex B longer |
| 0.008 | 0.007 | **0.015** |
| 0.011 | 0.009 | **0.019** |

(-4 deg C)

| FLEX C | | |
|---|---|---|
| Girder shorten (L=214.4) | Spool shorten (L= 99.2) | flex C lengthen |
| 0.008 | 0.007 | **0.014** |

| FLEX D | | |
|---|---|---|
| Girder shorten (L=226.4) | sect cbr shortn (L=222.8) | flex C longer |
| 0.008 | 0.015 | **0.007** |

**Case 2 — bake to 130 — 131-29=102**

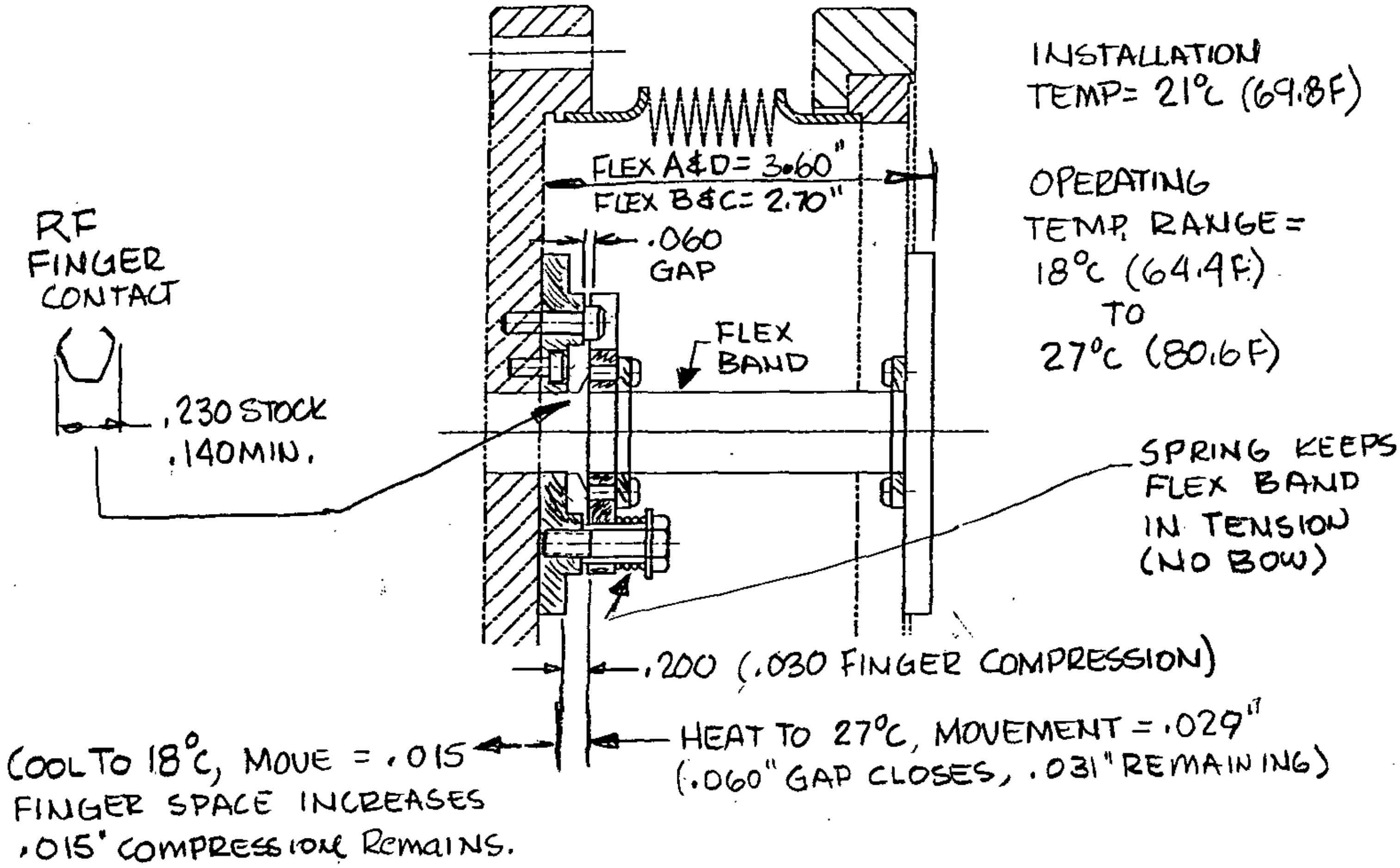
| FLEX A | | |
|---|---|---|
| | sect cbr elong (L=193.2) | flex A shorten |
| 131C bake | 0.434 | **0.434** |
| 121Cbake | 0.391 | |

| FLEX B | | |
|---|---|---|
| | Spool elong (L= 99.2) | flex B shorten |
| 131C bake | 0.223 | **0.223** |
| 121Cbake | 0.201 | |

| FLEX C | | |
|---|---|---|
| | Spool elong (L= 99.2) | flex C shorten |
| | 0.223 | **0.223** |

| FLEX D | | |
|---|---|---|
| | sect cbr elong (L=222.8) | flex C shorten |
| | 0.500 | **0.500** |

(Thermal deflections of RF flex joint bands are assumed to be neglagible for changes in temp of 4 to 6 Deg. C from nominal)
(Thermal movements of concrete floor are not considered in these Calcs)

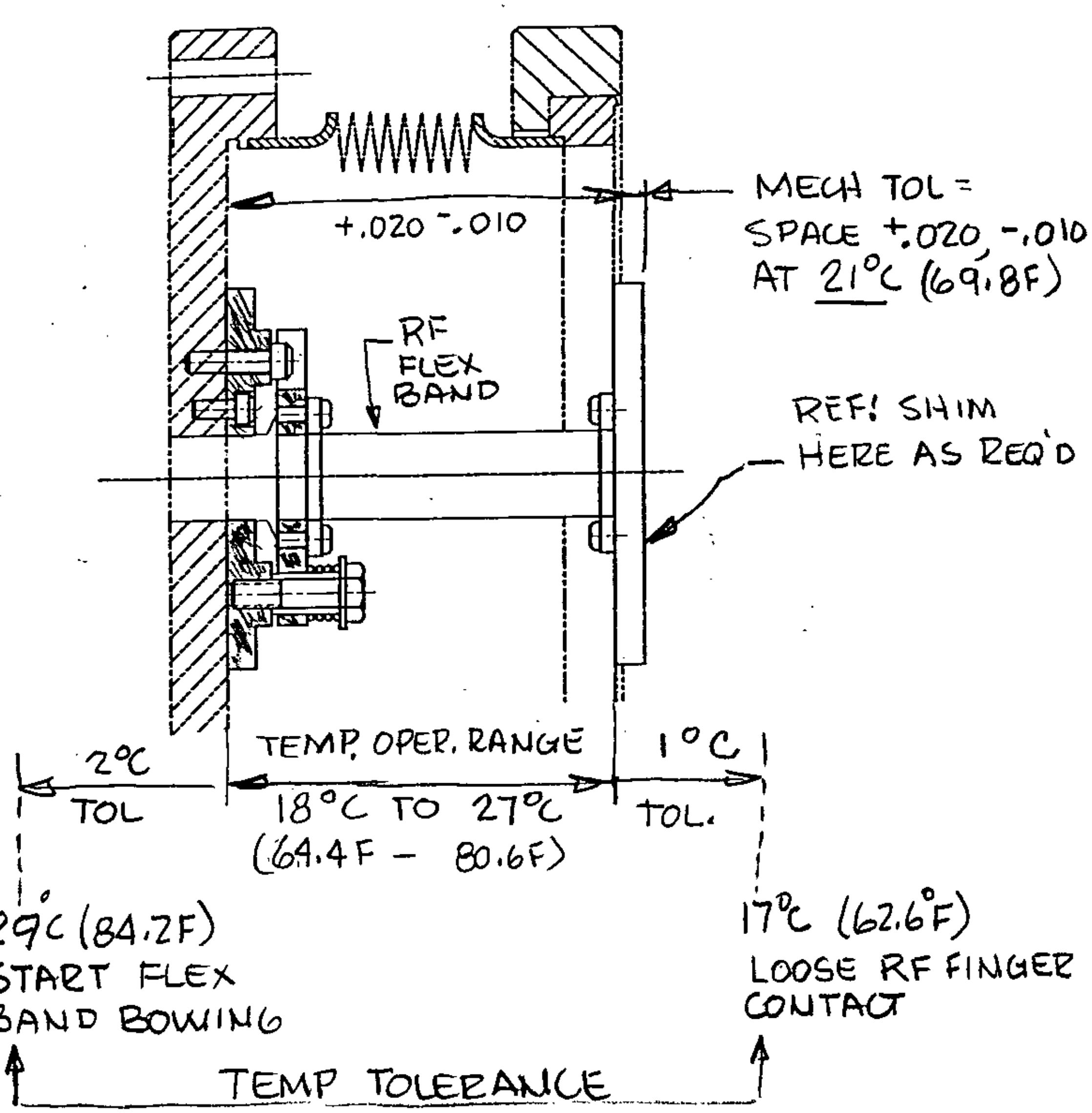



THINKING: IF ASSY. IS EXACTLY THE SAME AS SPACE BETWEEN FLANGES AT INSTALLATION TEMP. OF 21°C, THEN IF WE HEAT TO 27°C WE WILL HAVE .031" REMAINING TO STOP (START OF FLEX BAND BOWING). IF WE COOL TO 18°C WE WILL HAVE .015" LEFT UNTIL WE LOOSE RF FINGER CONTACT.

USING A PORTION OF MOVEMENT REMAINING ON BOTH ENDS FOR MECH. TOLERANCE, LETS USE .020" OF .031 ON THE WARM END AND .010 OF .015 ON THE COOL END.

NOW THE ASSY MUST = SPACE +.020", -.010"
INSTALLING A +.020 ASSY RESULTS IN .011" TO STOP AT 27°C — 1°C = ~.005" MOVEMENT SO WE HAVE ~2°C OVER TEMP. TOL.
INSTALLING A -.010 ASSY. RESULTS IN .005" COMPRESSION REMAINING OR ~1°C TEMP. TOL

# SUMMARY OF MECH. & TEMP. TOLERANCES




1°C = ~.048"
FLEX BAND
BOWING
AFTER 29°C

COMMENTS:

- SHIMMING WILL BE REQ'D IN ORDER TO ACHIEVE MECHANICAL TOLERANCES EVEN IF ADJACENT FLANGES ARE PARALLEL.
- WE PLAN TO HAVE .005" & .010" SHIMS ON HAND.
- WE MAY NEED TO CUSTOM FAB FLEX BANDS NOT ONLY FOR LENGTH BUT TO COMPENSATE FOR OUT OF PARALLEL FLANGES.

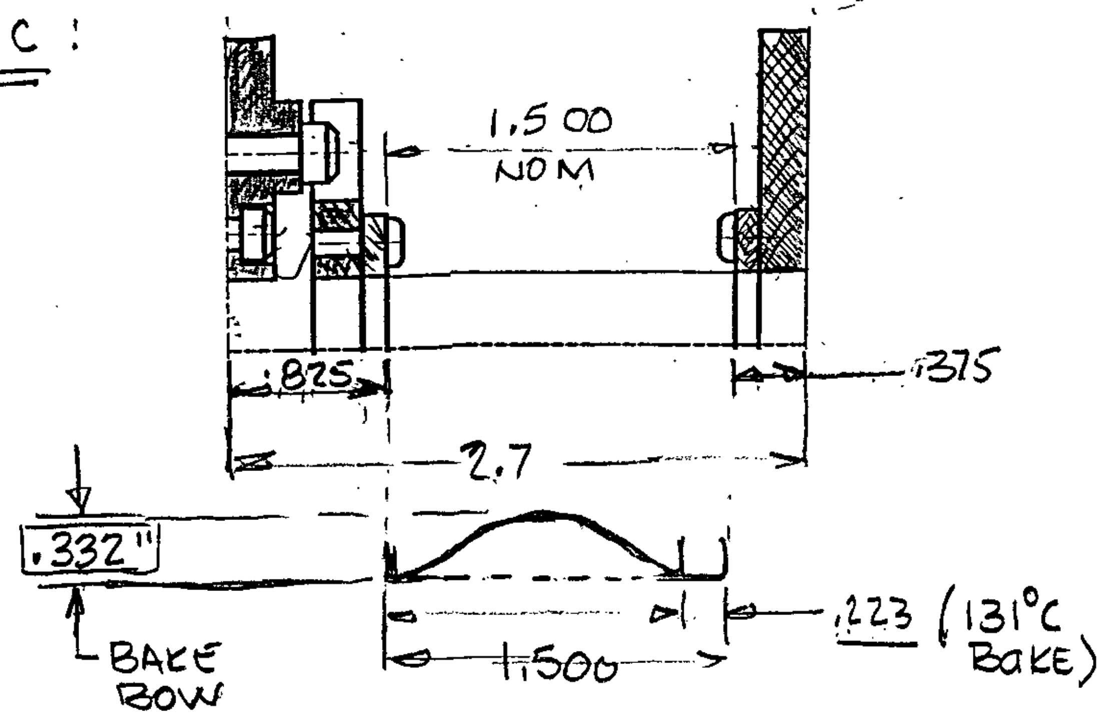
# FLEX BAND BOWING DURING BAKE:

AT 29°C WE START TO BOW FLEX BAND.
IF WE ASSUME AVERAGE INSITU BAKE
TEMP. OF 131°C THEN 131−29 = 102°C ΔT

FOR FLEX B&C THIS = ΔL OF .223" (2.7" NOM)

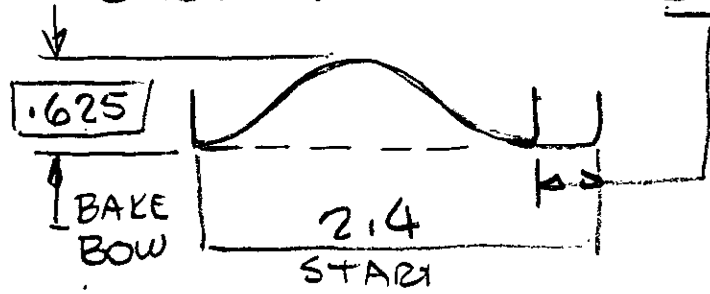
FOR FLEX A&D THIS = ΔL OF .500 (3.6" NOM)

## B&C:




## A&D

START LENGTH = 3.6
FLEX BAND = 3.6 − (.825 + .375) = 2.4"
BAKE MOVEMENT = .5" FOR 131°C



97.

LSME- 5 0 2 9 [illegible]

| LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA ENGINEERING NOTE | | CODE AL 0522 | SERIAL M7275 | PAGE 1 OF 15 |
|---|---|---|---|---|
| AUTHOR Jack Tanabe, Ken Rex | DEPARTMENT Mechanical Engineering | LOCATION Berkeley | | DATE May 12, 1992 |
| PROGRAM – PROJECT – JOB Advanced Light Source | | | | |
| Storage Ring– Magnet/Girder Installation | | | | |
| TITLE Water Flow | | | | |

Advanced Light Source

INTRODUCTION

R. T. Avery suggested a method of connecting the water circuits through the magnet and the Uniflex water cooled power cables which would minimize the vertical thermal ground motion due to heating of the cables which are installed in underground conduits. His suggested configuration would minimize the limited amount of flow available to the storage ring lattice by putting the cable flow in series with the magnet cooling flow. (See Engineering Note M7168A, LSME-417.) The connection configuration was discussed and agreed upon among R. Avery, B. Bailey, T. Henderson, J. Krupnick, A. Paterson, K. Rex and J. Tanabe. The magnets and cables for a single sector were connected in the suggested configuration during late February, 1992 by a crew headed by Wayne Oglesby. During preliminary troubleshooting and testing phase of the configuration, a flaw in the approach became apparent. Water flow through all the magnets in a single sector required flow through manifolds in adjacent sectors as well as through the manifolds in the sector under test. (Some of the flow through a feed manifold in a single sector would flow through return manifolds in adjacent sectors. )

It was impossible to isolate the flows through a single sector. Ken Rex suggested that the flow circuits be simplified by isolating the flows through the power cables from those through the magnets. In order to recover some of the additional water required by this scheme, he further suggested that the water through the power feed and power return cables be connected in series.

This engineering note is written in order to describe the water circuitry through all the magnets and their power cables, describe a test performed by Ken Rex and Wayne Oglesby and suggest the installation of orifices in some of the lines in order to restrict some of the flow.

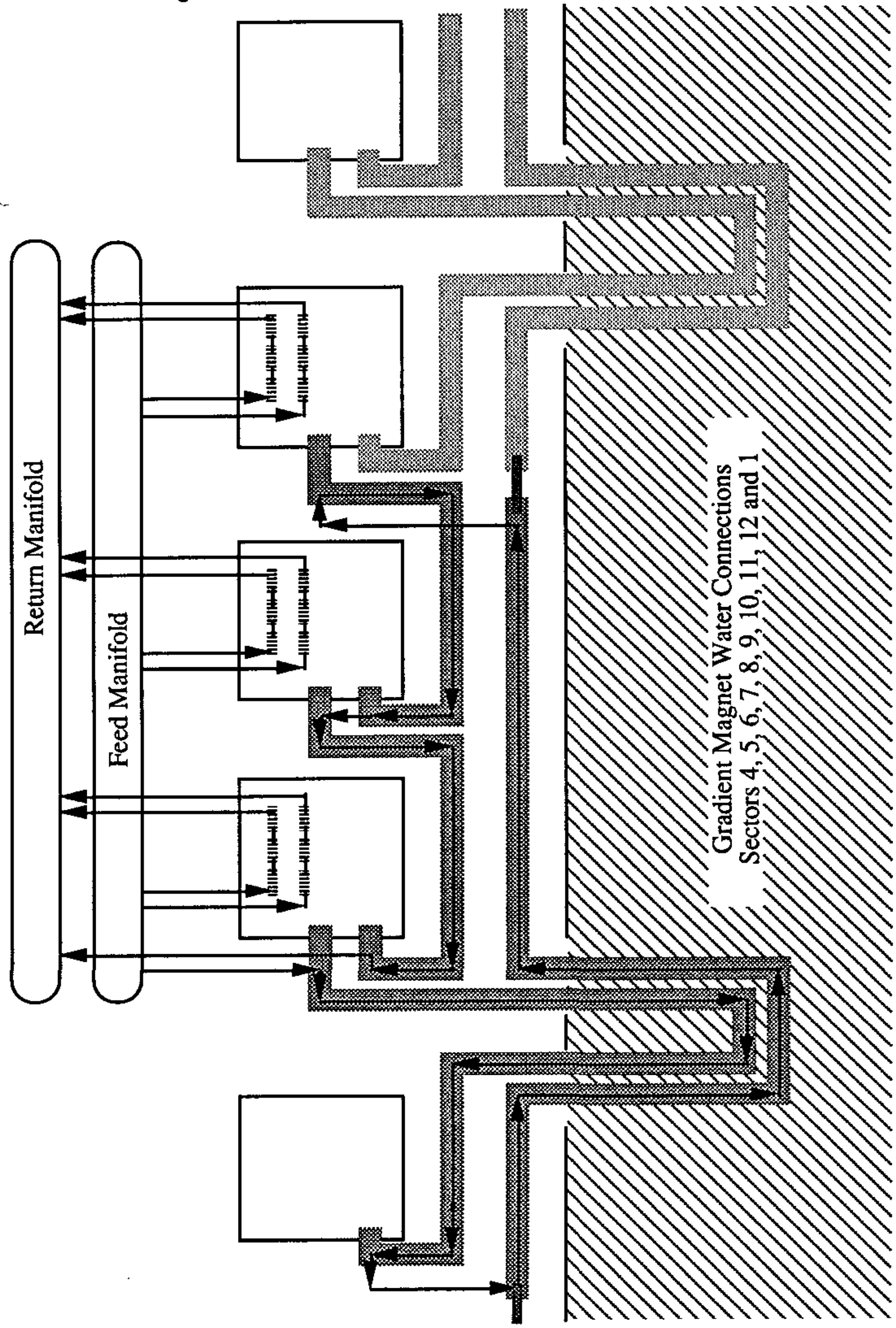
Initial Distribution:

Bob Avery Tom Henderson Bob Miller Wayne Oglesby Alan Paterson

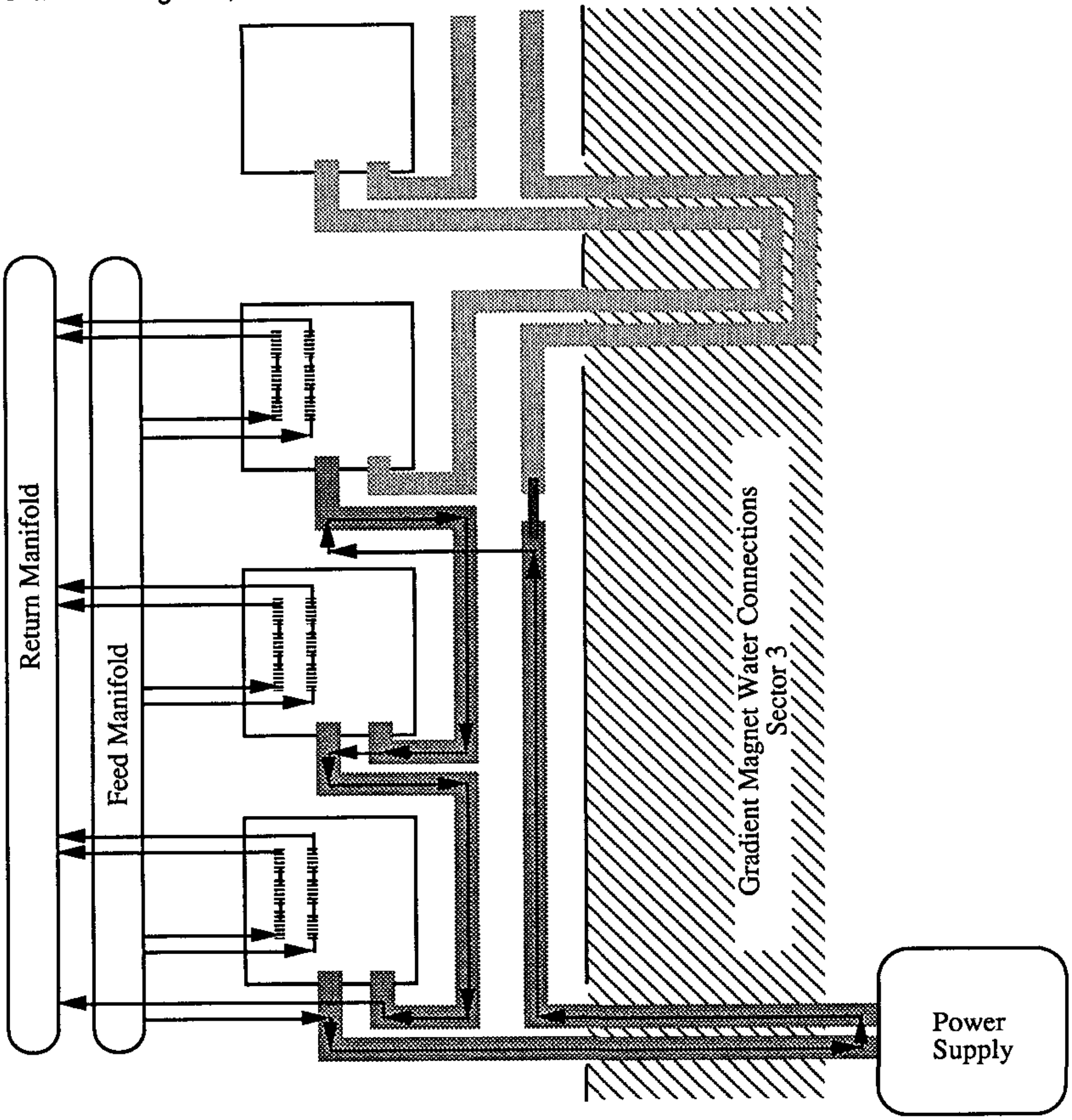
| LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA ENGINEERING NOTE | | CODE AL 0522 | SERIAL M7275 | PAGE 2 OF 15 |
|---|---|---|---|---|
| AUTHOR Jack Tanabe, Ken Rex | DEPARTMENT Mechanical Engineering | LOCATION Berkeley | | DATE May 12, 1992 |

# WATER CIRCUITRY

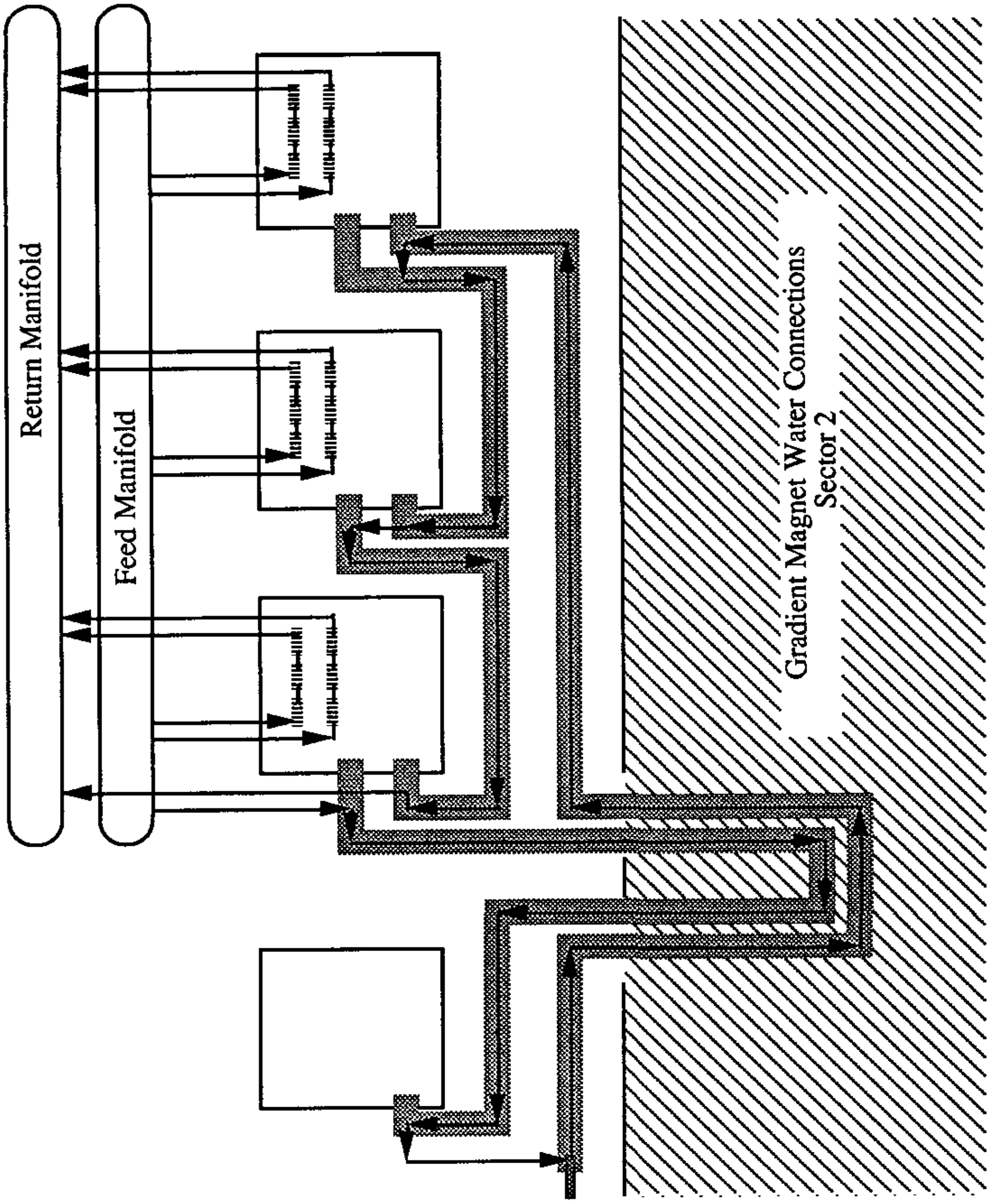
## Gradient Magnets; Sectors 4, 5, 6, 7, 8, 9, 10, 11, 12 and 1



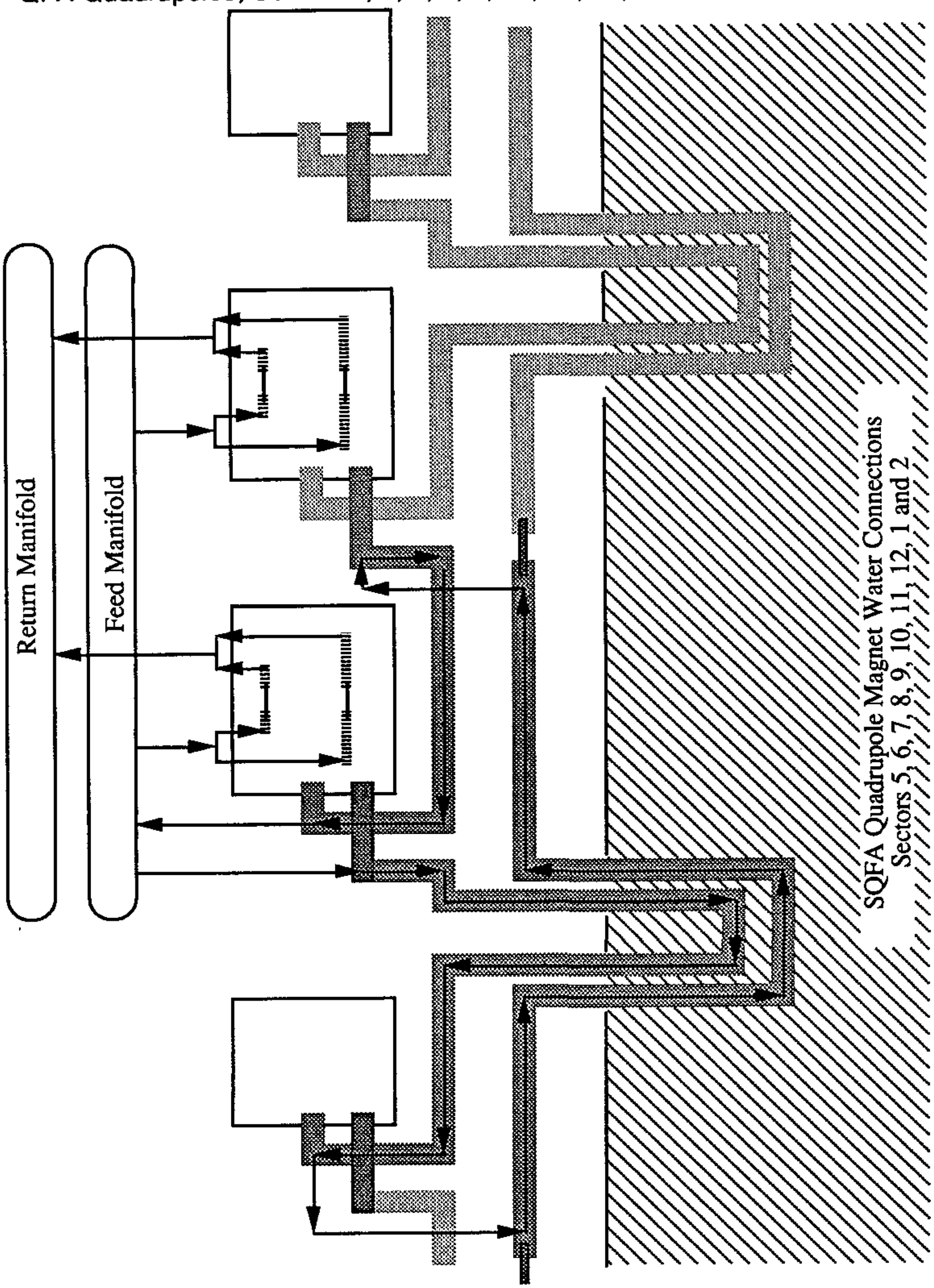
Gradient Magnets; Sector 3



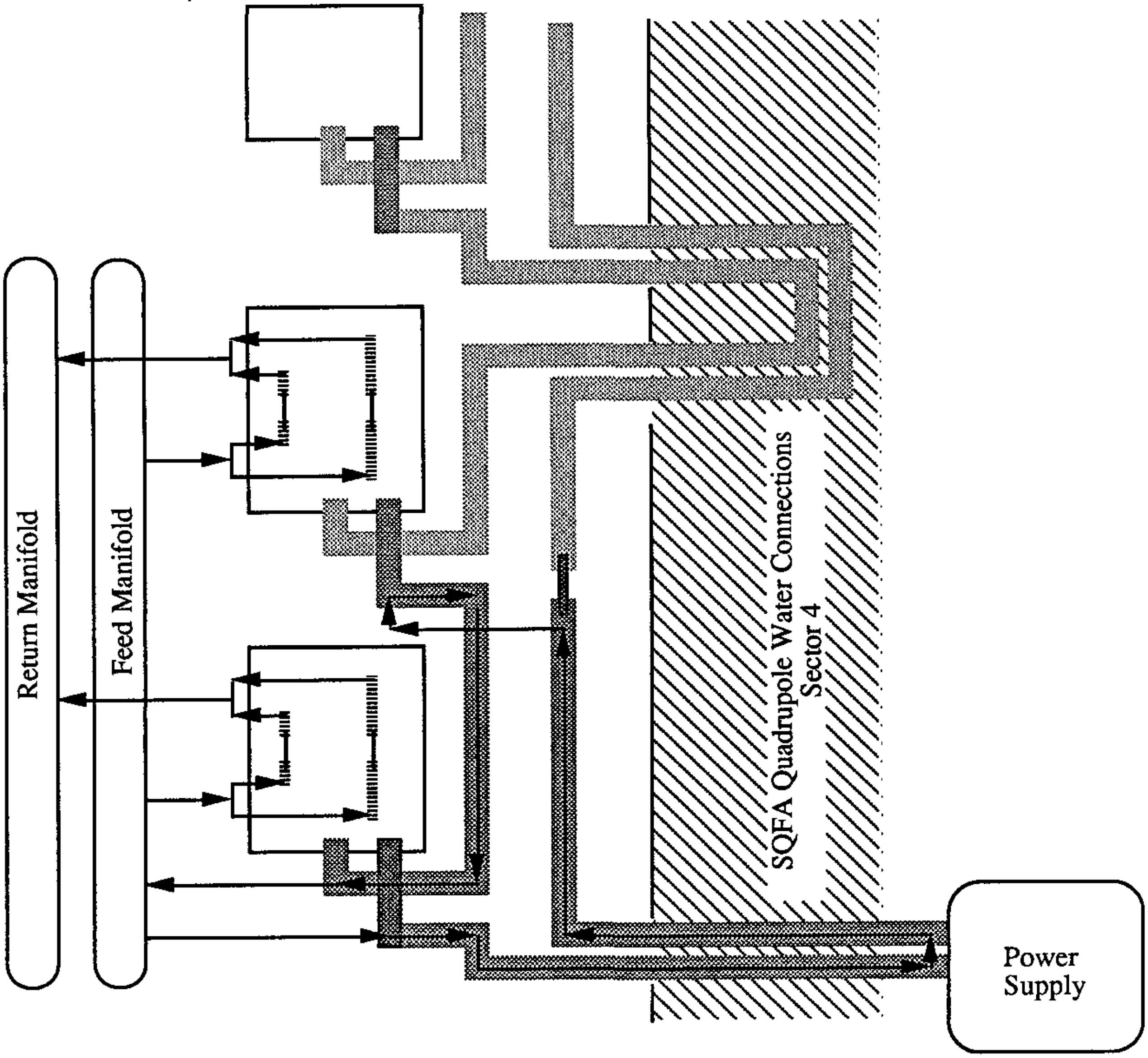
Gradient Magnets; Sector 2



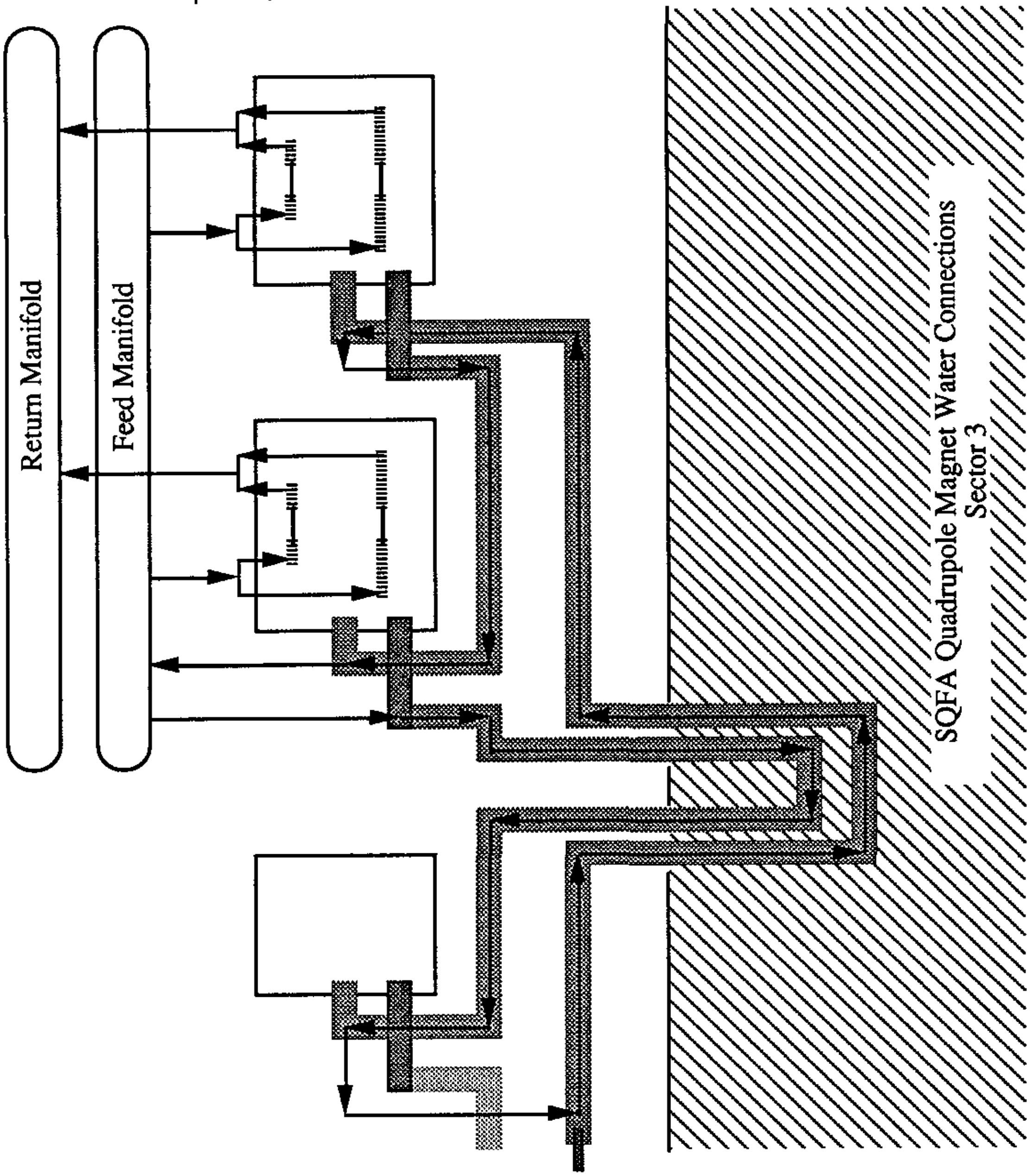
QFA Quadrupoles; Sectors 5, 6, 7, 8, 9, 10, 11, 12, 1 and 2



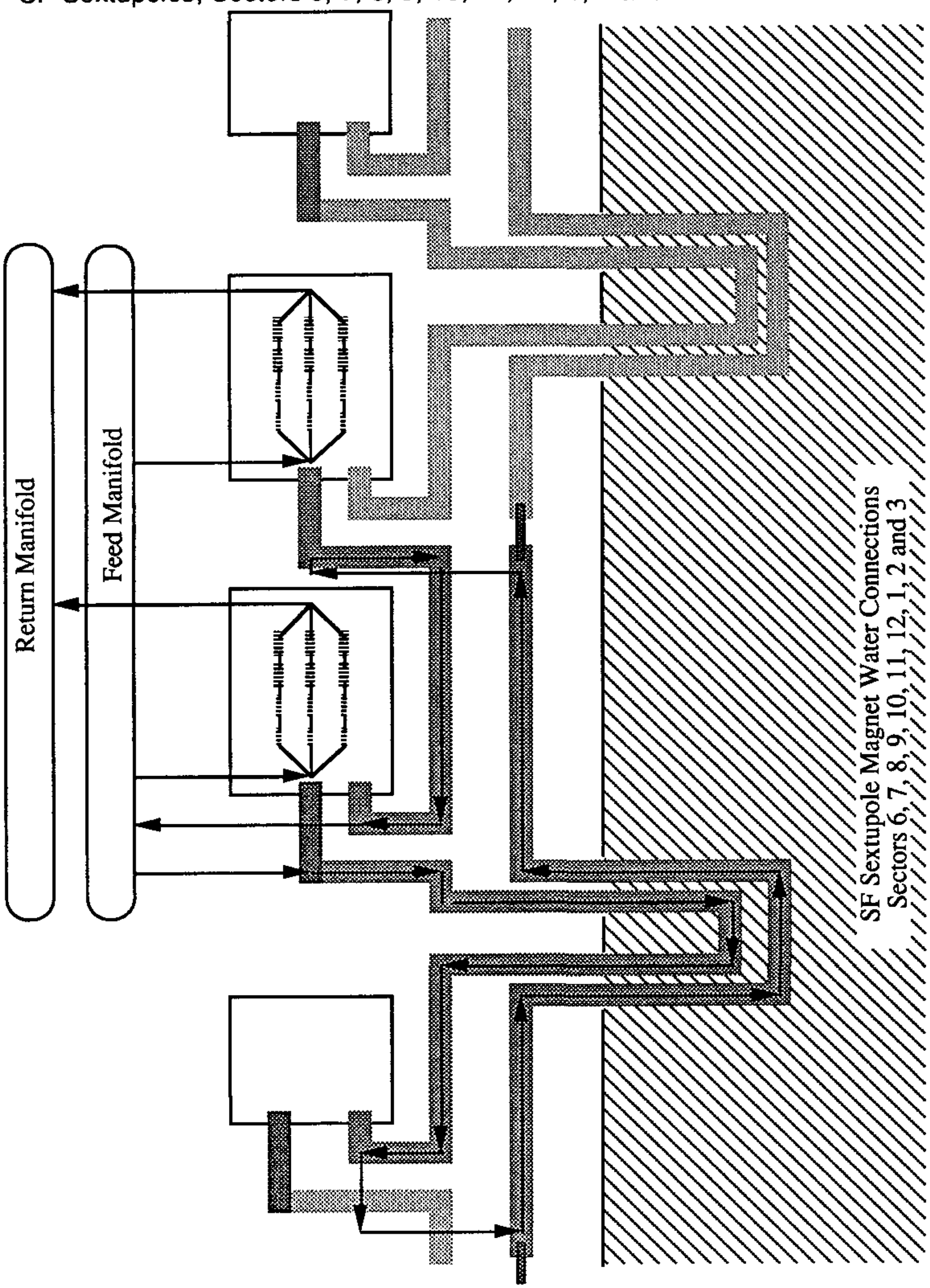
QFA Quadrupoles; Sector 4



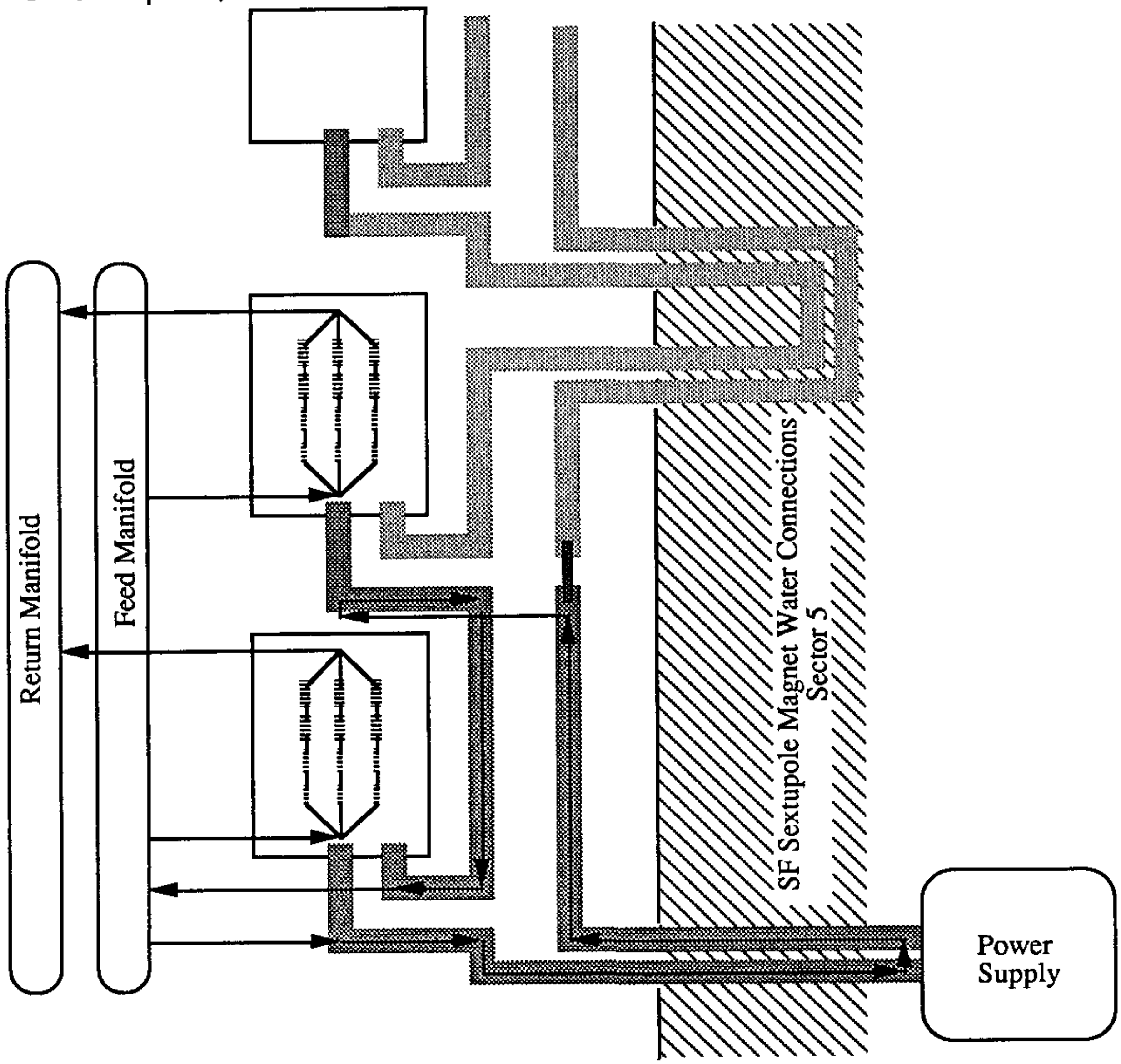
QFA Quadrupoles; Sector 3



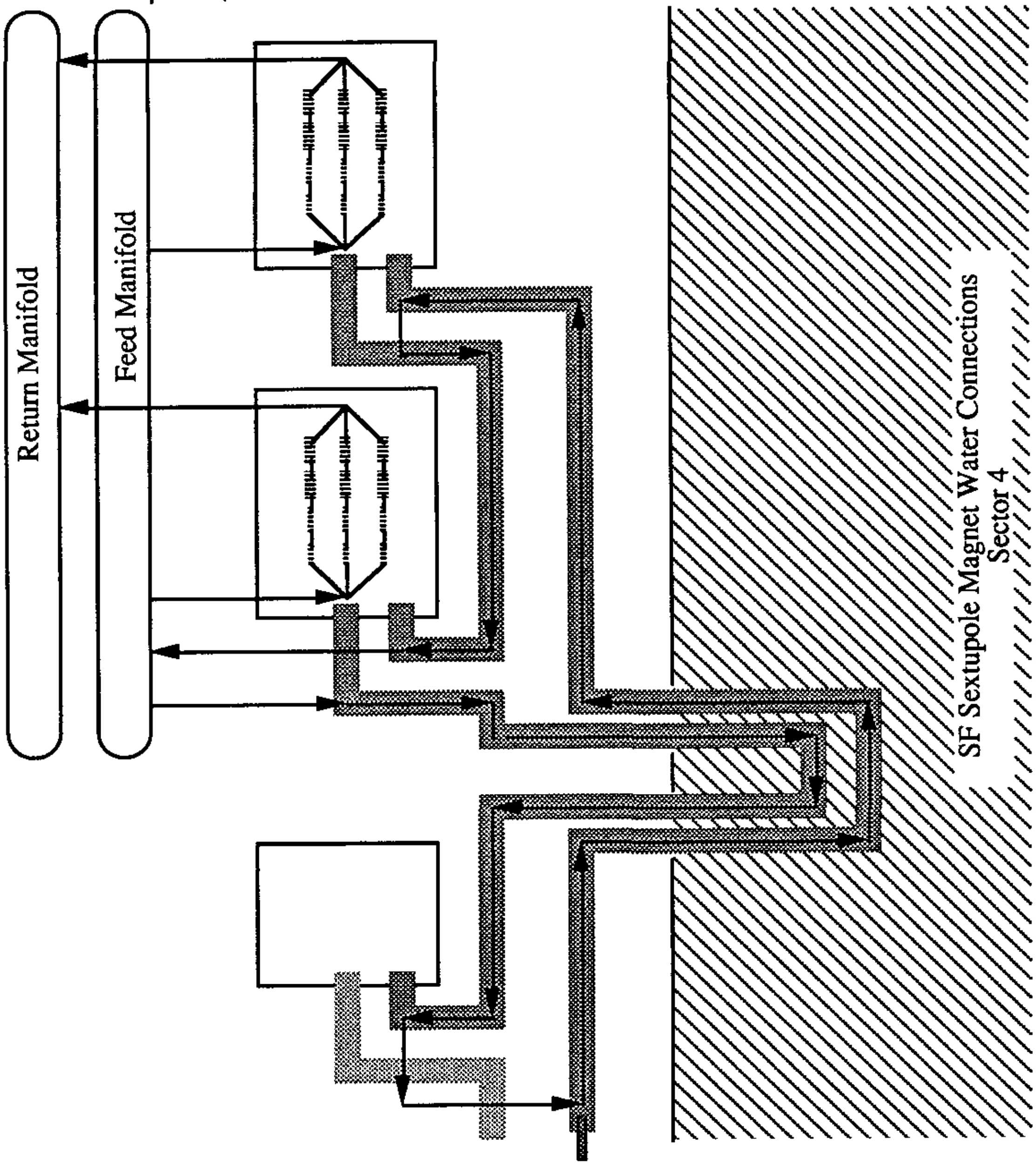
SF Sextupoles; Sectors 6, 7, 8, 9, 10, 11, 12, 1, 2 and 3



SF Sextupoles; Sector 5

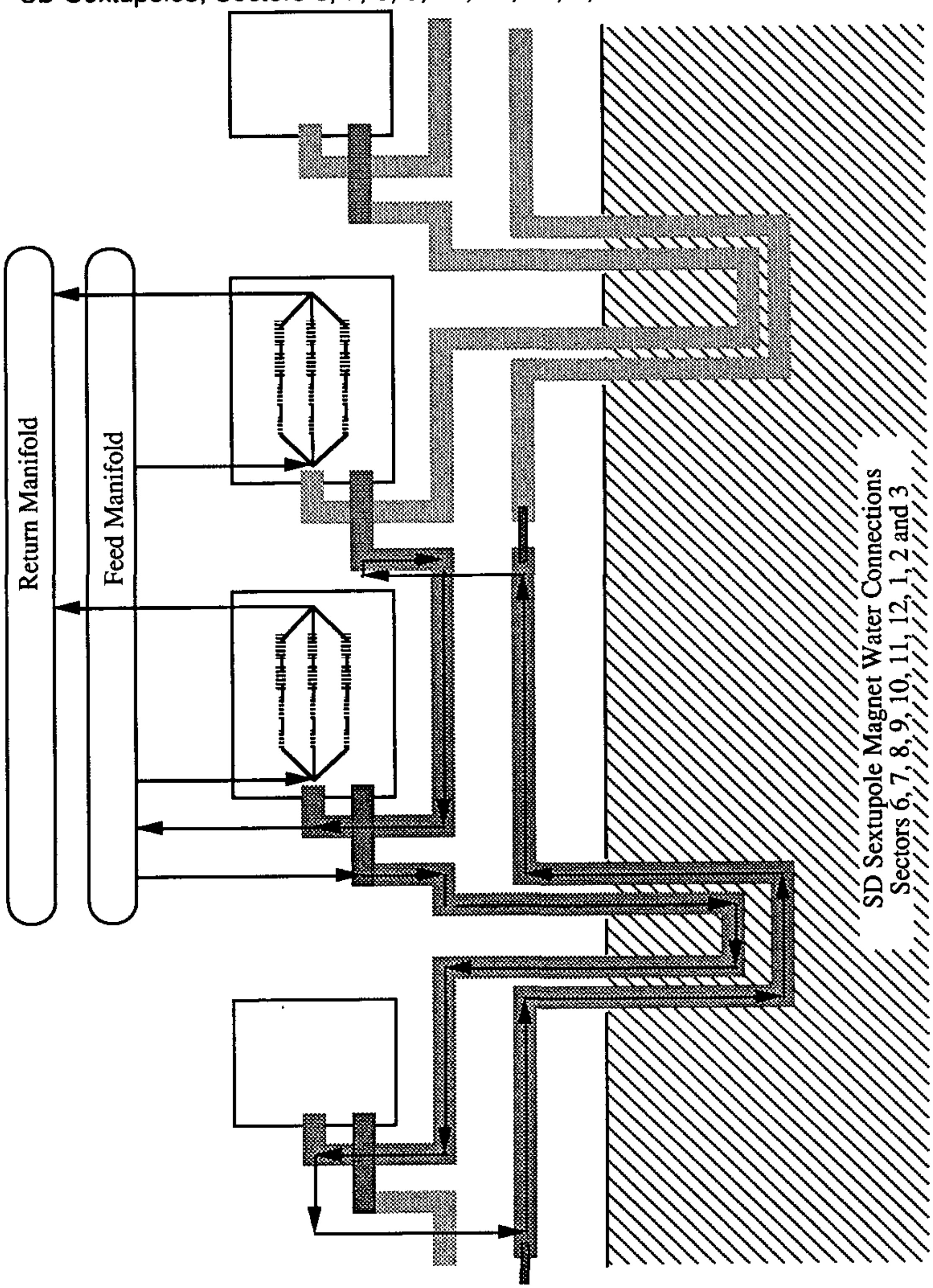


SF Sextupoles; Sector 4

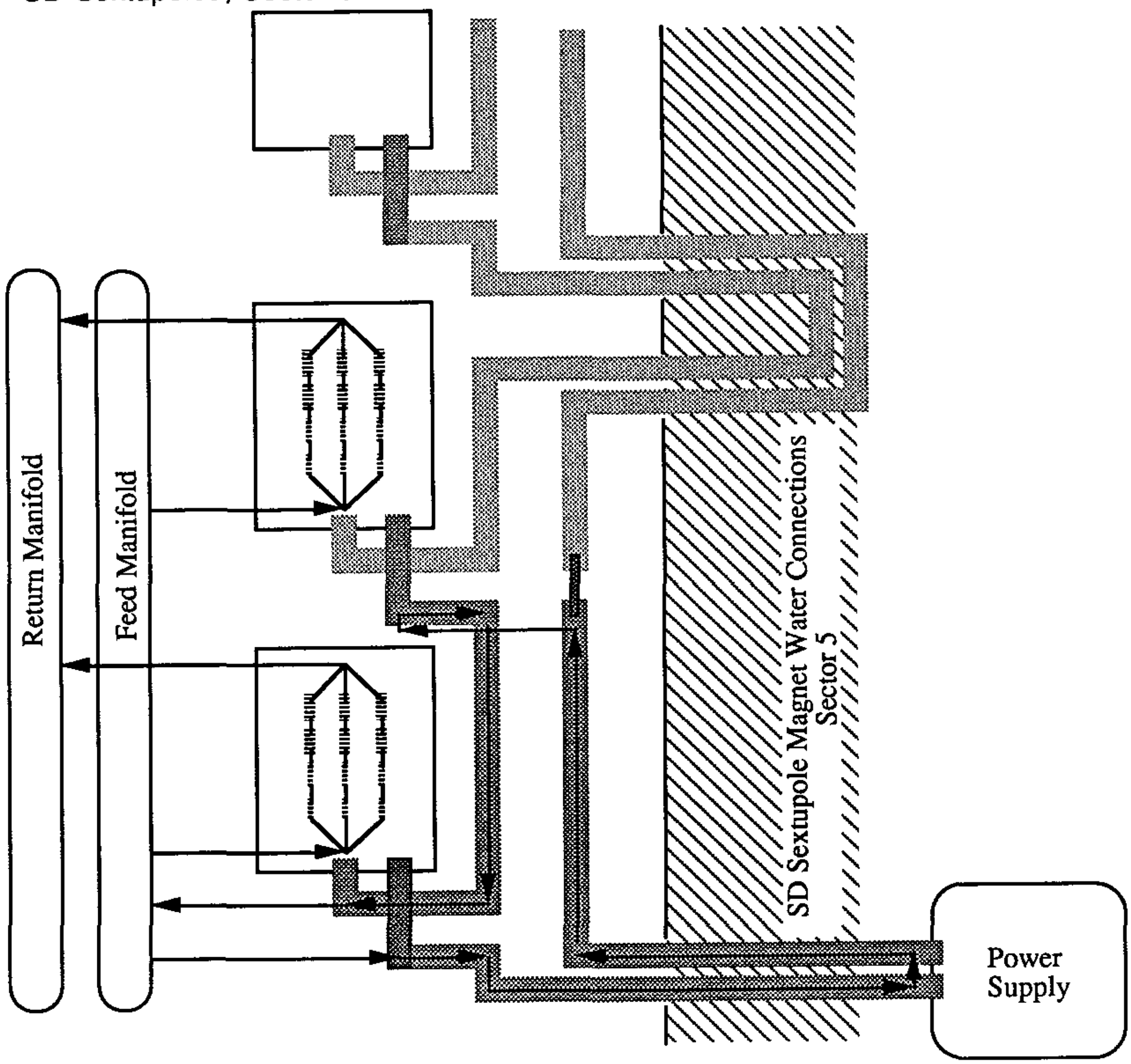


| AUTHOR | DEPARTMENT | LOCATION | DATE |
|---|---|---|---|
| Jack Tanabe, Ken Rex | Mechanical Engineering | Berkeley | May 12, 1992 |

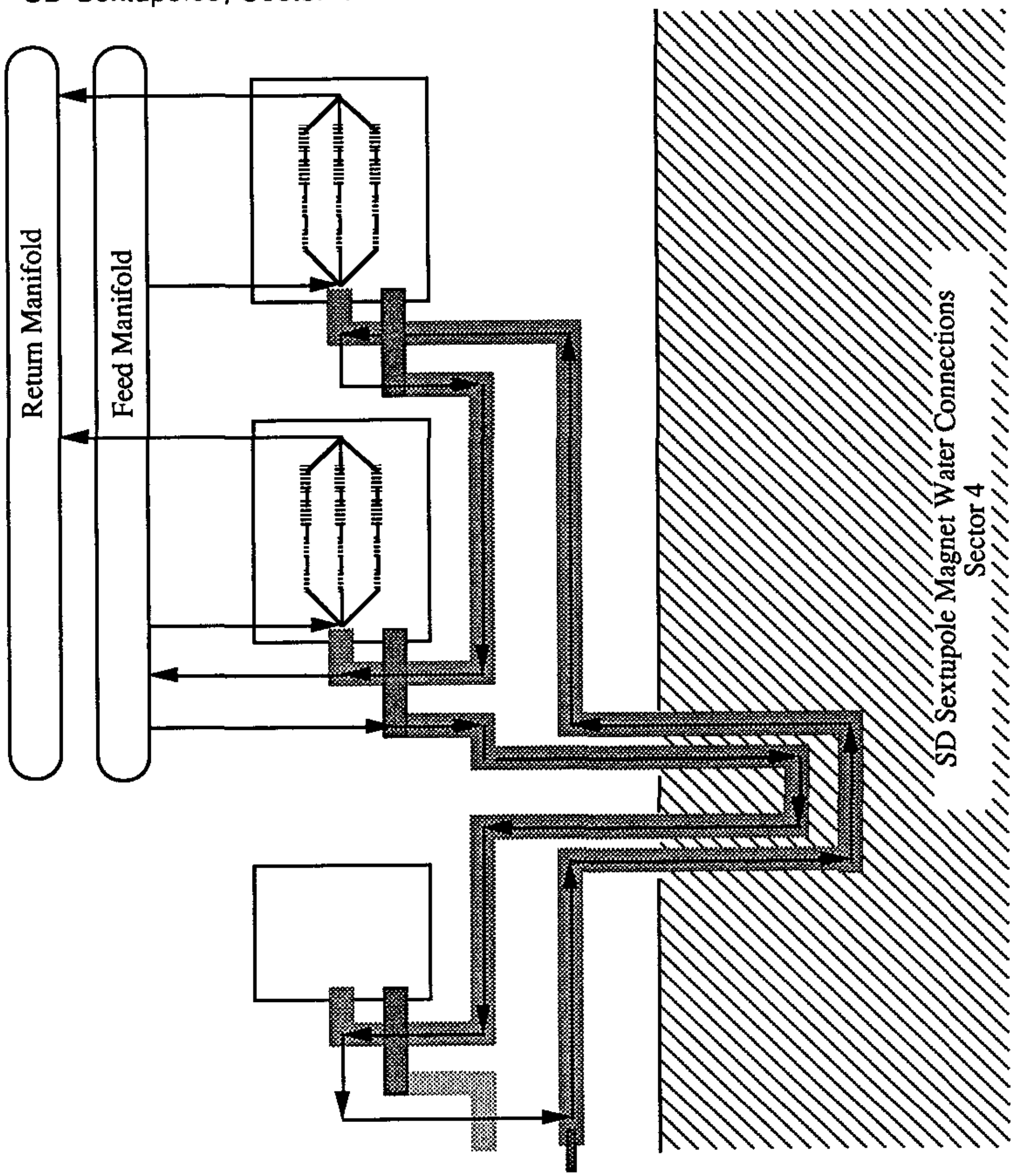

SD Sextupoles; Sectors 6, 7, 8, 9, 10, 11, 12, 1, 2 and 3



SD Sextupoles; Sector 5



SD Sextupoles; Sector 4



## MEASUREMENTS

Measurements were performed on the flow through a manifold supplying water to the magnets and water cables on girder SR10 using a flowmeter on the return leg of the water supply system. Flow measurements were made with all 17 magnets connected to the manifolds, then with each magnet removed from the circuit by "pinching" off and stopping the flow in one magnet at a time. The flow through each magnet is estimated by taking the difference between the total flow with and without the particular magnet in the line. Since the specific flow required by a magnet is as little as 0.3% and ranges as high as 5% of the total flow through a sector manifold, and since the reading accuracy of the flowmeter is not very precise for these small flow differentials, the measurements have a large error bar. Thus, the flow measurements through each magnet reported in this note must be taken "with a grain of salt". The flows through each magnet were individually measured during the magnet assembly procedure and are recorded in the specific magnet travellers. Thus, at best, the pinch tests are only an indication that the flows are approximately what is expected and, at worst, an indication that there is no blockage in the line caused by activity between the magnet assembly and installation onto a sector chamber.

On the other hand, the method of pinching the lines was the only method for estimating the flow through the power cables which feed the series connected magnets in the storage ring (gradient magnets, quadrupoles SQFA, and SF and SD sextupole families). These magnets are fed through water cooled cables which, between the girders, are installed in conduits which are cast in concrete under the storage ring floor. Because of alignment precision required for the elements in the storage ring, it was felt that vertical thermal motions due to the heating of the cables in the underground conduits should be minimized. Thus, it is important to provide sufficient water through the power cables to limit the temperature rise through these cables to some small value (say a few degrees C).

The following tables summarize the measurements and the calculations of the predicted temperature rise in each of the magnet systems and in the cables based on the measurements made by Ken Rex on storage ring girder SR10.

### FOR THE MAGNETS:

"Unpinched" Flow = 33.20 gpm

Flow Through a Circuit = Unpinched Flow - Pinched Flow

$$\Delta p \propto Q^{1.75} \quad \text{where:} \begin{pmatrix} \Delta p = \text{pressure drop} \\ Q = \text{Flow} \end{pmatrix}$$

$$Q \propto \Delta p^{\frac{1}{1.75}} \quad \rightarrow \quad Q_{@\ 60\ psi} = Q_{@\ 82\ psi}\left(\frac{60}{82}\right)^{0.5714}$$

$$\Delta T = \frac{3.8 \cdot P}{Q} \quad \text{where:} \begin{pmatrix} \Delta T = \text{Temperature Rise in °C} \\ P = \text{Power in kW} \\ Q = \text{Flow in gpm} \end{pmatrix}$$

| Magnets | Pinched Flow (gpm) | Flow @ 82 psi (gpm) | Flow @ 60 psi (gpm) | Resistance (Ω) | Max. Current (Amps) | Max. Power (kW) | ΔT (°C) |
|---|---|---|---|---|---|---|---|
| Gradient Magnet 1-Top Coil | 31.90 | 1.30 | 1.09 | 0.0067 | 911 | 5.56 | 19 |
| Bottom Coil | 31.80 | 1.40 | 1.17 | 0.0067 | 911 | 5.56 | 18 |
| Gradient Magnet 2 -Top Coil | 31.85 | 1.35 | 1.13 | 0.0067 | 911 | 5.56 | 19 |
| Bottom Coil | 31.80 | 1.40 | 1.17 | 0.0067 | 911 | 5.56 | 18 |
| Gradient Magnet 3 -Top Coil | 31.60 | 1.60 | 1.34 | 0.0067 | 911 | 5.56 | 16 |
| Bottom Coil | 31.50 | 1.70 | 1.42 | 0.0067 | 911 | 5.56 | 15 |
| SQFA Quadrupole 1 | 32.40 | 0.80 | 0.67 | 0.0266 | 488 | 6.33 | 36 |
| SQFA Quadrupole 2 | 32.40 | 0.80 | 0.67 | 0.0266 | 488 | 6.33 | 36 |
| SQF Quadrupole 1 | 32.60 | 0.60 | 0.50 | 0.3610 | 112 | 4.53 | 34 |
| SQF Quadrupole 2 | 32.60 | 0.60 | 0.50 | 0.3610 | 112 | 4.53 | 34 |
| SQD Quadrupole 1 | 32.40 | 0.80 | 0.67 | 0.2470 | 117 | 3.38 | 19 |
| SQD Quadrupole 2 | 32.40 | 0.80 | 0.67 | 0.2470 | 117 | 3.38 | 19 |
| SF Sextupole 1 | 31.40 | 1.80 | 1.51 | 0.0183 | 378 | 2.61 | 7 |
| SF Sextupole 2 | 31.50 | 1.70 | 1.42 | 0.0183 | 378 | 2.61 | 7 |
| SD Sextupole 1 | 31.50 | 1.70 | 1.42 | 0.0183 | 378 | 2.61 | 7 |
| SD Sextupole 2 | 31.50 | 1.70 | 1.42 | 0.0183 | 378 | 2.61 | 7 |
| Steering Magnet 1 | 33.15 | 0.05 | 0.04 | .1083/.0425 | 50/100 | 0.695 | *66 |
| Steering Magnet 2 | 33.02 | 0.18 | 0.15 | .1083/.0425 | 50/100 | 0.695 | 18 |
| Steering Magnet 3 | 33.00 | 0.20 | 0.17 | .1083/.0425 | 50/100 | 0.695 | 16 |

*Steering magnet 1 appears to have a high temperature. Flow measurements at these small values are questionable.

**FOR THE MAGNET CABLES:**

"Unpinched" Flow = 14.40 gpm

Flow Through a Circuit = Unpinched Flow - Pinched Flow

$$Q \propto \Delta p^{\frac{1}{1.75}} \rightarrow Q_{@\,60\,psi} = Q_{@\,92\,psi}\left(\frac{60}{92}\right)^{0.5714}$$

Gradient Magnet Cable Length = 788 + 159 + 159 + 676 = 1782 inches = 148.50 ft.

Gradient Magnet Cable = 750 MCM Cable = 16.26 μΩ/ft.

SQFA Quadrupole Cable Length = 822 + 192 + 746 = 1760 inches = 146.67 ft.

SQFA Quadrupole Cable = 500 MCM Cable = 24.40 μΩ/ft.

SD Sextupole Cable Length = 810 + 228 + 750 = 1788 inches = 149.00 ft.

SD Sextupole Cable = 350 MCM Cable = 34.86 μΩ/ft.

SF Sextupole Cable Length = 804 + 150 + 761 = 1715 inches = 142.92 ft.

SF Sextupole Cable = 350 MCM Cable = 34.86 μΩ/ft.

| Cables | Pinched Flow (gpm) | Flow @ 92 psi (gpm) | Flow @ 60 psi (gpm) | Length (ft.) | Resistance (mΩ) | Max. Current (Amps) | Max. Power (kW) | ΔT @ 60 psi (°C) |
|---|---|---|---|---|---|---|---|---|
| Gradient Magnet | 11.23 | 3.17 | 2.48 | 148.50 | 2.41 | 911 | 2.0039 | 3.1 |
| SQFA Quadrupole | 10.69 | 3.71 | 2.91 | 146.67 | 3.58 | 488 | 0.8522 | 1.1 |
| SD Sextupoles | 10.87 | 3.53 | 2.77 | 149.00 | 5.19 | 378 | 0.7422 | 1.0 |
| SF Sextupoles | 10.87 | 3.53 | 2.77 | 142.92 | 4.98 | 378 | 0.7119 | 1.0 |

For the cable flows, it is recommended to add an orifice to the SQFA Quadrupole, SD Sextupole and the SF sextupole cable water circuits in order to reduce their flow to approximately 1.5 gpm @ 60 psi. This will conserve water and increase the temperature rise in these circuits to approximately 2°C.

At 92 psi Δp, $Q_{@\,92\,psi} = 1.5\left(\frac{92}{60}\right)^{0.5714} = 1.9$ gpm.